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GB0308419.1

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Incorporated in the United Kingdom
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ADP No. 07649676002

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2. Patent application number (The Patent Office will fill in this part)	0308419.1 11 APR 2003		
3. Full name, address and postcode of the or of each applicant (underline all surnames)	Micromass Limited Atlas Park Simonsway Manchester M22 5PP United Kingdom E799732-1 D00027 02/06/03		
Patents ADP number (if you know it)	6996102003		
If the applicant is a corporate body, give country/state of incorporation	UK		
4. Title of the invention	Mass Spectrometer		
5. Name of your agent (if you have one)	Frank B. Dehn & Co.		
"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)	179 Queen Victoria Street London EC4V 4EL		
Patents ADP number (if you know it)	166001		
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17

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26

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MASS SPECTROMETER

5 The present invention relates to a mass spectrometer, an ion mobility separator, a method of mass spectrometry and a method of ion mobility separation.

10 Radio Frequency (RF) ion guides are commonly used for confining and transporting ions. Conventionally a plurality of electrodes are provided wherein an RF voltage is applied between neighbouring electrodes so that a pseudo-potential well or valley is produced. The pseudo-potential well can be arranged to confine ions 15 and may be used to efficiently transport ions by acting as an ion guide.

20 The RF ion guide is capable of functioning efficiently as an ion guide even at relatively high pressures wherein ions are likely to undergo frequent collisions with residual gas molecules. However, 25 although the collisions with gas molecules may cause the ions to scatter and lose energy, the pseudo-potential well generated by the RF ion guide acts to radially confine the ions within the ion guide. RF ion guides therefore have an advantage over guide wire types of ion 30 guides wherein a DC voltage is applied to a central wire running down the centre of a conducting tube. In such arrangements ions are held in orbit around the central guide wire and if ions undergo many collisions with gas molecules then they will tend to lose energy and will eventually collapse into the central guide wire and hence be lost. It is known to use RF ion guides to transport ions through vacuum chambers held at intermediate pressures (e.g. 0.001-10 mbar). For

- 2 -

example, the ion guide may be provided to transmit ion from an atmospheric pressure ion source to a mass analyser in a chamber maintained at a relatively low pressure.

5 When an ion collides with a gas molecule it may get scattered and lose kinetic energy. If the ion undergoes a large number of collisions, e.g. more than 100 collisions, then the ion will substantially lose all its forward kinetic energy. The ions will therefore possess
10 a mean energy which is substantially equal to that of the surrounding gas molecules. The ions will therefore appear to move randomly within the gas due to continuing random collisions with gas molecules. Accordingly,
15 under some operating conditions, ions being transported through an RF ion guide maintained at an intermediate gas pressure can lose substantially all their forward motion, and hence in theory at least these ions will remain within the ion guide for a relatively long period of time.

20 In practice, ions may still continue to move forwards for other reasons. It is normally assumed that ions may continue to move forwards due to the bulk movement of gas forcing the ions through the ion guide. Space charge effects caused by the continual ingress of ions into the ion guide and hence the electrostatic repulsion from ions arriving from behind may also effectively push the ions through the ion guide. However, without these influences the ions can, in effect, come to a substantial standstill within the ion
25 guide and hence not emerge at the exit.

30 A known means for driving ions through an RF ion guide at intermediate pressures is the use of an axial electric field. To ensure the ions emerge, or simply to

- 3 -

reduce their transit time, an axial voltage gradient may be applied along the ion guide. The axial electric fields may be applied in a number of ways. For example, axial electric fields may be applied to ion guides using 5 multipole rod sets by the use of segmented rods with a DC voltage between successive rods, by the use of inclined or tapered rods, or by the use of resistive rods with a DC voltage gradient along their length. Axial fields may be applied to ion guides using stacked 10 ring sets by applying a DC voltage to successive rings or groups of rings. Axial fields may also be applied by the use of additional electrodes, usually in the form of cylinders, external to the ion guide so that some of the axial field penetrates into the ion guide itself. In 15 all these cases the axial electric field causes the ions to accelerate forwards after each collision with a gas molecule. A very weak field, in the region of 0.1 to 1 V/cm, is adequate for pressures between 0.001 and 0.01 mbar. At higher pressures higher field strengths may be 20 used.

In the pressure region above 0.001 mbar ions in an axial field will attain velocities according to their ion mobility. When such drift tubes are used in conjunction with a pulsed ion source then separation of 25 ions according to their ion mobility is achieved.

According to a preferred embodiment a repeating pattern of electrical potentials are superimposed along the length of an ion guide so as to form a periodic waveform. The waveform is caused to travel along the 30 ion guide in the direction in which it is required to move the ions and at the velocity at which it is required to move the ions.

- 4 -

The ion mobility separator may comprise an RF ion guide such as a multipole rod set or a stacked ring set. The ion guide is segmented in the axial direction so that independent transient DC potentials can be applied
5 to each segment. The transient DC potentials are superimposed on top of an RF confining voltage and any constant DC offset voltage. The transient DC potentials generate a travelling wave which moves in the axial direction.

10 At any instant in time a voltage gradient is generated between segments which acts to push or pull ions in a certain direction. As the ions move in the required direction so does the voltage gradient. The individual DC voltages on each of the segments may be
15 programmed to create a required waveform. The individual DC voltages on each of the segments may also be programmed to change in synchronism so that the DC potential waveform is maintained but is translated in the direction in which it is required to move the ions.

20 Various embodiment of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

Fig. 1 shows equilibrium in a preferred ion mobility separator;

25 Fig. 2 shows a travelling wave beginning at one end of the preferred ion mobility separator;

Fig. 3 shows a travelling wave sweeping high mobility ions;

30 Fig. 4 shows all high mobility ions swept and ejected from the ion mobility separator;

Fig. 5 shows the preferred ion mobility separator portioned into two regions at equilibrium;

- 5 -

Fig. 6 shows higher mobility ions having been swept into a second region of the ion mobility separator and the travelling wave direction reversing in direction;

5 Fig. 7 shows an intermediate mobility left behind in a second stage (bandpass operation);

Fig. 8 shows a predetermined separation of two samples;

10 Fig. 9A shows a preferred travelling waveform, Fig. 9B shows another travelling waveform and Fig. 9C shows a further travelling waveform;

Fig. 10A shows the transit time recorded for Gramacidin-S (m/z 572) and Fig. 10B shows the transit time recorded for Leucine Enkephalin (m/z 556).

15 Fig. 1 shows a preferred ion mobility separator 1 comprising a plurality of electrodes 3 each having an aperture. Adjacent electrodes 3 are connected to opposite phases of an RF supply. The ion mobility separator 1 is preferably held at a pressure such that ions traversing its length undergo many collisions with 20 gas molecules. The ion mobility separator 1 may according to one embodiment receive ions generated by an Electrospray or MALDI ion source. The end plates 2a, 2b of the ion mobility separator 1 may be maintained at a slight positive voltage relative to the other electrodes 25 3 so that ions are trapped within the ion mobility separator 1 and are unable to surmount the potential barrier at either end. After a certain period of time equilibrium is reached within the ion mobility separator 1 so that ions of all masses and mobilities are 30 substantially equally distributed along the length of the ion mobility separator 1. According to one embodiment a voltage V_s is then applied to the first electrode in the ion guide adjacent to one of the end

- 6 -

plates 2a so that some ions will be pushed by the applied voltage along the ion mobility separator 1 as shown in Fig. 2 by the local field variation as given by the equation:

5

$$V_{drift} = KE(x)$$

where V_{drift} is the drift velocity of an ion, K is the mobility of the ion and E(x) is the electric field caused by the applied voltage. The electric field caused by the applied voltage decays rapidly to a negligible value within a few electrode spacings.

The voltage V_g is then preferably rapidly switched to the next adjacent electrode. An ion which has had enough time to drift at least one electrode spacing will therefore experience the same force and will again move along the ion mobility separator 1. However, ions of lower mobility may not have had sufficient time to drift far enough to see the influence of the voltage when it switched to the adjacent electrode and hence these ions will be effectively left behind.

The voltage pulse V_g preferably travels along the ion mobility separator 1 from electrode to electrode sweeping those ions with a sufficiently high ion mobility with it. As shown in Figs. 3 and 4, the ion mobility separator 1 may therefore in one embodiment act as a high pass ion mobility filter such that ions having ion mobilities greater than a certain value are preferably ejected from the ion mobility separator 1 whereas ions having lower ion mobilities remain substantially trapped within the ion mobility separator 1.

- 7 -

The sweep time of the ion mobility separator 1 T_{sweep} may then be reduced to select a slightly lower (intermediate) ion mobility so that those ions having an intermediate ion mobility may then be ejected from the ion mobility separator 1. By gradually further reducing the sweep time a complete mobility scan may be built up until the ion mobility separator 1 is substantially empty of ions.

Another way to scan the ion mobility separator 1 is to increase the voltage progressively with each sweep thereby collecting ions having progressively decreasing ion mobilities in the same way. It will be appreciated from consideration of the above equation that doubling the voltage will double the velocity of an ion.

The resolution of the ion mobility separator 1 is in part determined by the size of the sweep T_{sweep} time or voltage increment. The smaller the step between the adjacent sweeps the greater the resolution of the ion mobility separator 1.

The mode of operation described above builds up a mobility spectrum by a series of high pass further steps. However, isolation of a particular range of mobilities i.e. bandpass operation may also be achieved by employing a two stage device. As shown in Fig. 5, ions with an ion mobility greater than a certain value may be arranged to pass along a portion of the ion mobility separator 1. The ions then pass an electrode which is maintained at a certain potential 6 and into a second region 5 which is preferably substantially empty of ions. As shown in Fig. 6, once some ions have been swept into the second region 5 the travelling wave may then be reversed so as to sweep some ions from the second region 5 past the same or another electrode which

- 8 -

is maintained at a preferably lower potential 6' back into the first region 4. The reverse sweep may be faster and/or have a higher voltage so that as shown in Fig. 7 ions having ion mobilities within a desired range 5 remain trapped in the second region 5.

The resolution of the ion mobility separator 1 has been modelled to include the effect of diffusion of ions. Diffusion effects are known to degrade the resolution of conventional drift tube ion mobility separators and the relationship between the drift tube length and the applied axial voltage drop is given by:

$$\frac{|X|}{L} = \frac{0.173}{\sqrt{V}}$$

where mod X is the spatial spread due to diffusion, L is the length of the drift tube and V the applied axial voltage drop.

To increase the resolving power of a conventional mobility spectrometer longer drift tubes and higher voltages may be employed. However, an advantage of the preferred ion mobility separator 1 is that the voltage required can be a relatively low e.g. 10V at a pressure of 2 mbar. Furthermore, the low (10V) voltage only needs to be applied to a single electrode at any one point in time. The preferred ion mobility separator corresponds with approximately 1000V applied to a drift tube type ion mobility spectrometer comprising 100 electrodes.

The ion mobility separator 1 has been modelled as a series of electrodes with a voltage resident on each electrode for a certain period of time. Diffusion was introduced into the model as a random scattering component over the time of residence of the voltage on an element. The result of this simulation is shown in

- 9 -

Fig. 8 and predicts the complete separation of Gramacidin S (m/z 572) and Leucine Enkephalin (m/z 556). This result is for an ion mobility separator 1 with 100 electrodes and with a voltage of 7V being progressively applied along the length of the ion mobility separator 1. This result is comparable with the performance which may be expected from a known drift tube ion mobility separator of similar dimensions.

Further improvements in resolution may be achieved by sweeping the ions backwards and forwards through the same volume. This has the effect of increasing the effective length of the ion mobility separator 1 without actually increasing its physical dimensions. A more compact ion mobility separator than conventional ion mobility spectrometers is therefore provided according to a preferred embodiment. More passes through the ion mobility separator 1 allow for greater isolation of the desired species of ions. Ions may be purged from the swept volume after the passage of the travelling wave by switching the RF voltage OFF and allowing ions to diffuse out of that portion of the ion mobility separator 1. After a desired number of passes of the same volume the ions may be allowed out of the ion mobility separator 1 for subsequent mass analysis.

The ion mobility separator 1 according to the preferred embodiment can advantageously operate at duty cycles approaching 100% as it can eject only those ions of desired mobility whilst storing the other ions for further analysis. This is in contrast to a Field Asymmetric Ion Mobility Spectrometer (FAIMS) which is a scanning device whereby ions that are not transmitted are lost to the walls of the device.

- 10 -

The known drift tube ion mobility separator works by admitting a short pulse of ions (known as the gate pulse) and allowing them to disperse in an electric field according to their ion mobility. By trapping ions prior to the drift tube they can be accumulated whilst ions are being dispersed in the drift tube and duty cycles approaching 100% may be achieved. The separation is generally on the millisecond timescale so subsequent experiments must be amenable to this in order to be able to take advantage of the high duty cycle.

A charge state separation device wherein a quadrupole is scanned in synchronisation with the output of a drift tube is the subject of a pending application. However, losses in ion transmission may occur as ions that enter the quadrupole with a stable trajectory may find themselves unstable part way through the quad and so be lost.

With the preferred embodiment a quadrupole downstream of the ion mobility separator 1 can be set to a discrete mass to charge ratio transmission window so as to match the desired mobility range ejected by the ion mobility separator 1. This means that the desired ions are stable in the quadrupole all through the device. The equivalent to a scanning experiment can therefore be performed in a stepped manner with no loss in duty cycle as unejected ions are still stored by the ion mobility separator 1.

A trapping stage must be used in order to obtain a high duty cycle with a conventional drift tube type of mobility spectrometer when using a continuous ion source. Ions are admitted to the drift tube using gate pulses which are narrow compared to drift times of ions. An ion mobility spectrometer that disperses on the

- 11 -

millisecond timescale therefore requires a gate pulse of the order of microseconds to achieve the best resolution. The use of such gate pulses results in ion mobility discrimination at the entrance to the ion mobility spectrometer which results in reduced sensitivity and skewed spectra. The ion mobility separator according to the preferred embodiment has no need for a narrow gate pulse as the ion mobility separator can be filled with a longer pulse and so does not suffer from such problems.

In addition to embodiments wherein a single transient DC potential is translated along the length of the ion mobility separator in a travelling wave having a repeating waveform can also be used to separate ions according to their ion mobilities if implemented in a drift region of sufficient gas pressure. The wave amplitude and velocity can be arranged such that ions do not surf on a single pulse along the drift region but roll over the top of the pulses and hence receive a succession of nudges leading to an overall drift in the wave direction. The transit time of an ion through the ion mobility separator will therefore be dependent upon its ion mobility.

According to this embodiment a travelling wave ion guide may be provided for the drift region. The ion guide may comprise either a stack of plates or a segmented multipole. An ion trapping region upstream of the drift region may be provided with an ion gate to periodically pulse bunches of ions from the ion trap into the drift region.

Fig. 9A shows a simple mode of operation wherein a travelling wave has a periodic pulse of constant amplitude and velocity. Fig. 9B shows another mode of

- 12 -

operation wherein a reverse DC gradient is superimposed on the travelling wave so that the field acts between pulses to move ions back towards the upstream ion gate. Such a voltage waveform may enhance the separation

5 characteristics of the ion mobility separator 1 and may be used to prevent ions having an ion mobility less than a certain value from travelling with the travelling wave and exiting the ion mobility separator 1. Fig. 9C shows a further mode of operation wherein the height of the

10 pulse reduces along the drift region as the potential due to an axial gradient increases. Such a waveform may also enhance separation. Furthermore, in this mode ions having a certain ion mobility may find balance points along the drift region where the movement caused by the

15 travelling wave is counteracted by the reverse axial gradient. Ions of different mobility may find balance points at different positions along the ion mobility separator. By this means a static mobility separation could be produced. Ions of similar mobility may collect

20 in specific regions. These ions may be transmitted in a band-pass operation. This mode of operation does not necessarily require an ion gate since it may operate with a continuous ion beam. Furthermore, the DC axial field may be constant or variable with position. This

25 may be achieved by applying potentials to the electrodes forming the ion guide which increase linearly or non-linearly. Alternatively, the amplitude of the travelling wave may decrease linearly or non-linearly as it progresses from the entrance to the exit of the ion

30 mobility separator. The DC axial field and amplitude of the travelling wave may change with position. In one particular embodiment the DC axial field may continuously increase from the entrance to the exit of

- 13 -

the ion mobility separator whilst the amplitude of the travelling wave remains constant.

The DC axial gradient, the amplitude of the travelling wave and the velocity of the travelling wave may also change with time. Hence, ions of differing mobility may first be separated spatially along the length of the ion guide and then moved along the ion guide to one end or the other. Ions may therefore be caused to exit the ion mobility separator in order of their mobility.

For example, ions that have been separated according to their ion mobility may be caused to move to the exit of the ion mobility separator by either reducing the DC potential gradient or by increasing the amplitude of the travelling wave. These ions may also be moved to the exit end by reducing the velocity of the travelling wave, or by reducing the gas pressure. Ions may also be caused to move by changing a combination of these controls. In this example ions may then be caused to leave the device in order of their mobility, starting with ions of highest mobility.

Alternatively, the separated ions may be caused to move to the entrance of the ion mobility separator either by increasing the DC potential gradient, by reducing the amplitude of the travelling wave, by increasing the velocity of the wave, or by increasing the gas pressure. Again a combination of these parameters may be changed to cause movement of the ions. In this example ions may then be caused to be emitted from the ion mobility separator via the entrance in order of their mobility starting with ions of lowest mobility.

- 14 -

According to an embodiment the pulse amplitude, wave velocity, pressure and axial gradient may be varied during operation so as to enhance the separation.

Although the ion mobility separator 1 as described above may be used in isolation for the analysis of a substance by means of measurement of the mobility of its component parts, it may also be used in isolation for separation, collection and storage of components of a substance.

The ion mobility separator 1 may also be used in combination with a mass spectrometer or tandem mass spectrometer. The combination with a mass spectrometer provides a means of analysis with greater specificity. It also provides a means of separation, collection and storage of component fractions of a substance, and therefore provides a means by which more components of a substance may be subsequently analysed in a mass spectrometer in greater detail.

A reversed axial voltage gradient could also be used to enhance separation by constantly returning ions not carried along completely by the travelling wave pulse to the entrance of the separation region.

Experimented data will now be presented. Ions were collected in an ion tunnel arrangement consisting of a stack of 90 ring electrodes each 0.5 mm thick and spaced apart by 1.0 mm. The central aperture of each ring was 5.0 mm diameter and the total length of the ion tunnel was 134 mm. A 2.1 MHz RF voltage was applied between neighbouring rings to confine the ion beam. Ions were retained in the ion tunnel by raising the DC potential at each end by approximately 5V. The pressure in the ion tunnel was about 10^{-3} mbar.

- 15 -

Ions were continuously generated using an electrospray ion source and continuously directed into the ion tunnel. The DC potential at the exit end of the ion guide was periodically reduced to allow ions to leave the ion tunnel. Ions were repeatedly collected and stored for 11 msec and then released over a period of 26 ns. Ions leaving the ion tunnel were accelerated through a 3 V potential difference and were then passed through a quadrupole rod set. The quadrupole was operating with only RF voltage applied to the rods so that is it was not acting as a mass filter. The ions exiting the quadrupole rod set then entered a travelling wave ion guide.

The travelling wave ion guide device consisted of a similar ion tunnel to that used for collecting and storing ions. The tunnel arrangement consisted of a stack of 122 ring electrodes, each 0.5 mm thick and spaced apart by 1.0 mm. The central aperture within each ring was 5.0 mm diameter and the total length of ring stack was 182 mm. A 2.4 MHz RF voltage was applied between neighbouring rings to confine the ion beam. The pressure in the ion tunnel was about 2×10^{-2} mbar. The travelling wave consisted of a regular periodic pulse of constant amplitude and velocity.

The travelling wave was generated by applying a DC voltage to a single ring electrode, and every subsequent ring displaced by nine rings along the ring stack. Hence, one wave-length λ of the waveform consisted of one ring with raised DC potential followed by eight rings at a lower potential. Thus the wavelength λ was equivalent to 9 rings, or 13.5 mm, and the total ion guide was equivalent to approximately 13.5 λ . The

- 16 -

travelling wave was generated by applying approximately 0.65V to each ring electrode for 5 ns before moving the applied voltage to the next ring. Thus the wave period or cycle time t was 45 nS. This was repeated uniformly 5 throughout the length of the travelling wave ion guide. Thus the wave velocity was equal to a constant 300 m/s.

At the exit of the travelling wave ion guide the ions passed through a second quadrupole rod set. This had both RF and DC supplies and could be tuned to 10 transmit ions having a particular mass to charge ratio. The ions were detected using an ion detector positioned after the second quadrupole rod set.

A mixture of Gramacidin-S (mol wt 1142 daltons) and Leucine Enkephalin (mol wt 555 daltons) were 15 continuously introduced into an Electrospray ion source. Singly charged protonated ions of Leucine Enkephalin (m/z 556) and doubly charged protonated ions of Gramacidin-S (m/z 572) were collected and stored in the first ion tunnel. These ions were periodically released 20 and their transit times to the ion detector were recorded. The transit times were recorded on an oscilloscope and are shown in Fig. 10. For each measurement the second quadrupole was tuned to just transmit either m/z 556 for Leucine Enkephalin or m/z 25 572 for Gramacidin-S.

The trace for Gramacidin-S is shown in Fig. 10A and shows that the peak arrival time for ions was about 2.2 msec after release from the first ion tunnel. The corresponding trace for Leucine Enkephalin is shown in 30 Fig. 10B and shows the corresponding peak arrival time was about 3.1 msec after release from the ion tunnel. Timing cursors showed that the transit time for Gramacidin-S was 940 ns less than that for Leucin

- 17 -

Enkephalin. This is in spite of the fact that the m/z value for Gramacidin-S (572) is marginally greater than that for Leucine Enkephalin (556) and that the Gramacidin-S molecule (mol wt 1142 daltons) is larger than the Leucine Enkephalin molecule (mol wt 555 daltons). A shorter transit time for Gramacidin-S would have been expected however since the m/z 572 ion is doubly charged and experiences twice the force due to the electric field of the travelling wave than that experienced by the singly charged Leucine Enkephalin ion at m/z 556. Although the doubly charged Gramicidin-S ion experienced twice the force, it did not experience twice the viscous drag since its cross sectional area is not twice that of Leucine Enkephalin. It might be expected their relative cross sectional areas are in the ratio approximately $(1144/556)^{2/3}$ which is approximately 1.6. Hence the Gramacidin-S ion is more mobile than the Leucine Enkephalin ion in the presence of the same electric field and same high gas pressure and therefore is less likely to slip over the tops of the waves in the travelling wave ion guide. As a result, the transit time for Gramacidin-S in the travelling wave ion guide was found to be less than that for Leucine Enkephalin. In fact its overall transit time is less than that for Leucine Enkephalin despite the fact that the Leucine Enkephalin ions with the lower m/z value will travel slightly faster through the two quadrupoles.

This experiment demonstrates how two ions with substantially similar mass to charge ratios but having different charge states (z values) may be separated by the travelling wave ion mobility separator according to the preferred embodiment.

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Claims

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1. A mass spectrometer comprising:
an ion mobility separator for separating ions
according to their ion mobility, said ion mobility
separator comprising a plurality of electrodes wherein
in use one or more transient DC voltages or one or more
transient DC voltage waveforms are progressively applied
to said electrodes so that at least some ions having a
first ion mobility are separated from other ions having
a second different ion mobility.

10
2. A mass spectrometer as claimed in claim 1, wherein
said DC voltage is such that at least 10%, 20%, 30%,
40%, 50%, 60%, 70%, 80%, 90% or 95% of said ions having
said first ion mobility are substantially moved along
said ion mobility separator by said one or more
transient DC voltages or said one or more transient DC
voltage waveforms as said one or more transient DC
voltages or said one or more transient DC voltage
waveforms are progressively applied to said electrodes..

20
3. A mass spectrometer as claimed in claim 1 or 2,
wherein said one or more transient DC voltages or said
one or more transient DC voltage waveforms are such that
at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or
95% of said ions having said second ion mobility are
moved along said ion mobility separator by said applied
DC voltage to a lesser degree than said ions having said
first ion mobility as said one or more transient DC
voltage waveforms are progressively applied to said electrodes.

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- 2 -

voltages or said one or more transient DC voltage waveforms are progressively applied to said electrodes.

4. A mass spectrometer as claimed in claim 1, 2, or 3,
5 wherein said one or more transient DC voltages or said
one or more transient DC voltage waveforms are such that
at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or
95% of said ions having said first ion mobility are
moved along said ion mobility separator with a higher
10 velocity than said ions having said second ion mobility.

5. A mass spectrometer comprising:
an ion mobility separator for separating ions
according to their ion mobility, said ion mobility
15 separator comprising a plurality of electrodes wherein
in use one or more transient DC voltages or one or more
transient DC voltage waveforms are progressively applied
to said electrodes so that ions are moved towards a
region of the ion mobility separator wherein at least
20 one electrode has a potential such that at least some
ions having a first ion mobility will pass across said
potential whereas other ions having a second different
ion mobility will not pass across said potential.

25 6. A mass spectrometer as claimed in claim 5, wherein
said one or more transient DC voltages or said one or
more transient DC voltage waveforms are such that at
least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or 95%
of said ions having said first ion mobility pass across
30 said potential.

7. A mass spectrometer as claimed in claim 5 or 6,
wherein said one or more transient DC voltages or said

- 3 -

one or more transient DC voltage waveforms are such that at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or 95% of said ions having said second ion mobility will not pass across said potential.

5

8. A mass spectrometer as claimed in claim 5, 6 or 7, wherein said at least one electrode is provided with a voltage such that a potential hill or valley is provided.

10

9. A mass spectrometer as claimed in any preceding claim, wherein said one or more transient DC voltages or said one or more transient DC voltage waveforms are such that at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or 95% of said ions having said first ion mobility exit said ion mobility separator substantially before ions having said second ion mobility.

15

10. A mass spectrometer as claimed in any preceding claim, wherein said one or more transient DC voltages or said one or more transient DC voltage waveforms are such that at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or 95% of said ions having said second ion mobility exit said ion mobility separator substantially after ions having said first ion mobility.

20

11. A mass spectrometer as claimed in any preceding claim, wherein a majority of said ions having said first ion mobility exit said ion mobility separator a time t before a majority of said ions having said second ion mobility exit said ion mobility separator, wherein t falls within a range selected from the group consisting of: (i) < 1 μ s; (ii) 1-10 μ s; (iii) 10-50 μ s; (iv) 50-

- 4 -

100 μ s; (v) 100-200 μ s; (vi) 200-300 μ s; (vii) 300-400
5 μ s; (viii) 400-500 μ s; (ix) 500-600 μ s; (x) 600-700 μ s;
(xi) 700-800 μ s; (xii) 800-900 μ s; (xiii) 900-1000 μ s;
(xiv) 1.0-1.1 ms (xv) 1.1-1.2 ms; (xvi) 1.2-1.3 ms;
(xvii) 1.3-1.4 ms; (xviii) 1.4-1.5 ms; (xix) 1.5-1.6 ms;
(xx) 1.6-1.7 ms; (xxi) 1.7-1.8 ms; (xxii) 1.8-1.9 ms;
(xxiii) 1.9-2.0 ms; (xxiv) 2.0-2.5 ms; (xxv) 2.5-3.0 ms;
(xxvi) 3.0-3.5 ms; (xxvii) 3.5-4.0 ms; (xxviii) 4.0-4.5
10 ms; (xxix) 4.5-5.0 ms; (xxx) 5-10 ms; (xxxi) 10-15 ms;
(xxxii) 15-20 ms; (xxxiii) 20-25 ms; and (xxxiv) 25-30
ms.

12. A mass spectrometer comprising:

an ion mobility separator for separating ions
15 according to their ion mobility, said ion mobility
separator comprising a plurality of electrodes wherein
in use one or more transient DC voltages or one or more
transient DC voltage waveforms are progressively applied
to said electrodes so that:

20 (i) ions are moved towards a region of the ion
mobility separator wherein at least one electrode has a
first potential such that at least some ions having
first and second ion mobilities will pass across said
first potential whereas other ions having a third
25 different ion mobility will not pass across said first
potential; and then

30 (ii) ions having said first and second ion
mobilities are moved towards a region of the ion
mobility separator wherein at least one electrode has a
second potential such that at least some ions having
said first ion mobility will pass across said second
potential whereas other ions having said second ion
mobility will not pass across said second potential.

- 5 -

13. A mass spectrometer as claimed in claim 12, wherein
said one or more transient DC voltages or said one or
more transient DC voltage waveforms and said first
5 potential are such that at least 10%, 20%, 30%, 40%,
50%, 60%, 70%, 80%, 90% or 95% of said ions having said
first ion mobility pass across said first potential.
14. A mass spectrometer as claimed in claim 12 or 13,
10 wherein said one or more transient DC voltages or said
one or more transient DC voltage waveforms and said
first potential are such that at least 10%, 20%, 30%,
40%, 50%, 60%, 70%, 80%, 90% or 95% of said ions having
said second ion mobility pass across said first
15 potential.
15. A mass spectrometer as claimed in claim 12, 13 or
14, wherein said one or more transient DC voltages or
said one or more transient DC voltage waveforms and said
20 first potential are such that at least 10%, 20%, 30%,
40%, 50%, 60%, 70%, 80%, 90% or 95% of said ions having
said third ion mobility do not pass across said first
potential.
- 25 16. A mass spectrometer as claimed in any of claims 12-
15, wherein said one or more transient DC voltages or
said one or more transient DC voltage waveforms and said
second potential are such that at least 10%, 20%, 30%,
40%, 50%, 60%, 70%, 80%, 90% or 95% of said ions having
30 said first ion mobility pass across said second
potential.

- 6 -

17. A mass spectrometer as claimed in any of claims 12-
16, wherein said one or more transient DC voltages or
said one or more transient DC voltage waveforms and said
second potential are such that at least 10%, 20%, 30%,
40%, 50%, 60%, 70%, 80%, 90% or 95% of said ions having
5 said second ion mobility do not pass across said second
potential.

18. A mass spectrometer as claimed in any of claims 12-
10 17, wherein said one or more transient DC voltages or
said one or more transient DC voltage waveforms are such
that at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%,
90% or 95% of said ions having said second ion mobility
exit said ion mobility separator substantially before
15 ions having said first and third ion mobilities.

19. A mass spectrometer as claimed in any of claims 12-
18, wherein said one or more transient DC voltages or
said one or more transient DC voltage waveforms are such
20 that at least 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%,
90% or 95% of said ions having said first and third ion
mobilities exit said ion mobility separator
substantially after ions having said second ion
mobility.

25 20. A mass spectrometer as claimed in any of claims 12-
19, wherein a majority of said ions having said second
ion mobility exit said ion mobility separator a time t
before a majority of said ions having said first and
30 third ion mobilities exit said ion mobility separator,
wherein t falls within a range selected from the group
consisting of: (i) < 1 μ s; (ii) 1-10 μ s; (iii) 10-50 μ s;
(iv) 50-100 μ s; (v) 100-200 μ s; (vi) 200-300 μ s; (vii)

- 7 -

300-400 μ s; (viii) 400-500 μ s; (ix) 500-600 μ s; (x) 600-
700 μ s; (xi) 700-800 μ s; (xii) 800-900 μ s; (xiii) 900-
1000 μ s; (xiv) 1.0-1.1 ms (xv) 1.1-1.2 ms; (xvi) 1.2-1.3
ms; (xvii) 1.3-1.4 ms; (xviii) 1.4-1.5 ms; (xix) 1.5-1.6
ms; (xx) 1.6-1.7 ms; (xxi) 1.7-1.8 ms; (xxii) 1.8-1.9
ms; (xxiii) 1.9-2.0 ms; (xxiv) 2.0-2.5 ms; (xxv) 2.5-3.0
ms; (xxvi) 3.0-3.5 ms; (xxvii) 3.5-4.0 ms; (xxviii) 4.0-
4.5 ms; (xxix) 4.5-5.0 ms; (xxx) 5-10 ms; (xxxi) 10-15
ms; (xxxii) 15-20 ms; (xxxiii) 20-25 ms; and (xxxiv) 25-
10 30 ms.

21. A mass spectrometer as claimed in any preceding
claim, wherein said one or more transient DC voltages
create: (i) a potential hill or barrier; (ii) a
15 potential well; (iii) a combination of a potential hill
or barrier and a potential well; (iv) multiple potential
hills or barriers; (v) multiple potential wells; or (vi)
a combination of multiple potential hills or barriers
and multiple potential wells.

20 22. A mass spectrometer as claimed in any preceding
claim, wherein said one or more transient DC voltage
waveforms comprise a repeating waveform.

25 23. A mass spectrometer as claimed in claim 22, wherein
said one or more transient DC voltage waveforms comprise
a square wave.

30 24. A mass spectrometer as claimed in any preceding
claim, wherein said one or more transient DC voltage
waveforms create a plurality of potential peaks or wells
separated by intermediate regions.

- 8 -

25. A mass spectrometer as claimed in claim 24, wherein
the DC voltage gradient in said intermediate regions is
non-zero.

5 26. A mass spectrometer as claimed in claim 25, wherein
said DC voltage gradient is positive or negative in said
intermediate regions.

10 27. A mass spectrometer as claimed in claim 25 or 26,
wherein the DC voltage gradient in said intermediate
regions is linear.

15 28. A mass spectrometer as claimed in any of claims 25
or 26, wherein the DC voltage gradient in said
intermediate regions is non-linear.

20 29. A mass spectrometer as claimed in claim 28, wherein
said DC voltage gradient in said intermediate regions
increases or decreases exponentially.

30. A mass spectrometer as claimed in any of claims 24-
29, wherein the amplitude of said potential peaks or
wells remains substantially constant.

25 31. A mass spectrometer as claimed in any of claims 24-
29, wherein the amplitude of said potential peaks or
wells becomes progressively larger or smaller.

30 32. A mass spectrometer as claimed in claim 31, wherein
the amplitude of said potential peaks or wells increases
or decreases either linearly or non-linearly.

- 9 -

33. A mass spectrometer as claimed in any preceding claim, wherein in use an axial voltage gradient is maintained along at least a portion of the length of said ion mobility separator and wherein said axial voltage gradient varies with time.

10 34. A mass spectrometer as claimed in any preceding claim, wherein said ion mobility separator comprises a first electrode held at a first reference potential, a second electrode held at a second reference potential, and a third electrode held at a third reference potential, wherein:

15 at a first time t_1 a first DC voltage is supplied to said first electrode so that said first electrode is held at a first potential above or below said first reference potential;

20 at a second later time t_2 a second DC voltage is supplied to said second electrode so that said second electrode is held at a second potential above or below said second reference potential; and

25 at a third later time t_3 a third DC voltage is supplied to said third electrode so that said third electrode is held at a third potential above or below said third reference potential.

35.

34. A mass spectrometer as claimed in claim 34, wherein:

30 at said first time t_1 said second electrode is at said second reference potential and said third electrode is at said third reference potential;

at said second time t_2 said first electrode is at said first potential and said third electrode is at said third reference potential; and

- 10 -

at said third time t_3 , said first electrode is at said first potential and said second electrode is at said second potential.

- 5 36. A mass spectrometer as claimed in claim 34,
wherein:

at said first time t_1 , said second electrode is at said second reference potential and said third electrode is at said third reference potential;

- 10 at said second time t_2 said first electrode is no longer supplied with said first DC voltage so that said first electrode is returned to said first reference potential and said third electrode is at said third reference potential; and

- 15 at said third time t_3 , said first electrode is at said first reference potential said second electrode is no longer supplied with said second DC voltage so that said second electrode is returned to said second reference potential.

20

37. A mass spectrometer as claimed in any of claims 34-36, wherein said first, second and third reference potentials are substantially the same.

- 25 38. A mass spectrometer as claimed in any of claims 34-37, wherein said first, second and third DC voltages are substantially the same.

- 30 39. A mass spectrometer as claimed in any of claims 34-38, wherein said first, second and third potentials are substantially the same.

- 11 -

40. A mass spectrometer as claimed in any preceding claim, wherein said ion mobility separator comprises 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30 or >30 segments, wherein each segment comprises 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30 or >30 electrodes electrically connected to each other.
- 10 41. A mass spectrometer as claimed in claim 40, wherein a plurality of segments are electrically connected to each other.
- 15 42. A mass spectrometer as claimed in claim 40 or 41, wherein each segment is electrically connected to the subsequent nth segment wherein n is 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30 or >30.
- 20 43. A mass spectrometer as claimed in any preceding claim, wherein ions are confined radially within said ion mobility separator by an AC or RF electric field.
- 25 44. A mass spectrometer as claimed in any preceding claim, wherein ions are radially confined within said ion mobility separator in a pseudo-potential well and are moved axially by a real potential barrier or well.
- 30 45. A mass spectrometer as claimed in any preceding claim, wherein the transit time of ions through said ion mobility separator is selected from the group consisting of: (i) less than or equal to 20 ms; (ii) less than or equal to 10 ms; (iii) less than or equal to 5 ms; (iv)

- 12 -

less than or equal to 1 ms; and (v) less than or equal to 0.5 ms.

46. A mass spectrometer as claimed in any preceding
5 claim, wherein said ion mobility separator is maintained
in use at a pressure selected from the group consisting
of: (i) greater than or equal to 0.0001 mbar; (ii)
greater than or equal to 0.0005 mbar; (iii) greater than
or equal to 0.001 mbar; (iv) greater than or equal to
10 0.005 mbar; (v) greater than or equal to 0.01 mbar; (vi)
greater than or equal to 0.05 mbar; (vii) greater than
or equal to 0.1 mbar; (viii) greater than or equal to
0.5 mbar; (ix) greater than or equal to 1 mbar; (x)
greater than or equal to 5 mbar; and (xi) greater than
15 or equal to 10 mbar.

47. A mass spectrometer as claimed in any preceding
claim, wherein said ion mobility separator is maintained
in use at a pressure selected from the group consisting
20 of: (i) less than or equal to 10 mbar; (ii) less than or
equal to 5 mbar; (iii) less than or equal to 1 mbar;
(iv) less than or equal to 0.5 mbar; (v) less than or
equal to 0.1 mbar; (vi) less than or equal to 0.05 mbar;
(vii) less than or equal to 0.01 mbar; (viii) less than
25 or equal to 0.005 mbar; (ix) less than or equal to 0.001
mbar; (x) less than or equal to 0.0005 mbar; and (xi)
less than or equal to 0.0001 mbar.

48. A mass spectrometer as claimed in any preceding
30 claim, wherein said ion mobility separator is
maintained, in use, at a pressure selected from the
group consisting of: (i) between 0.0001 and 10 mbar;
(ii) between 0.0001 and 1 mbar; (iii) between 0.0001 and

- 13 -

- 0.1 mbar; (iv) between 0.0001 and 0.01 mbar; (v) between 0.0001 and 0.001 mbar; (vi) between 0.001 and 10 mbar; (vii) between 0.001 and 1 mbar; (viii) between 0.001 and 0.1 mbar; (ix) between 0.001 and 0.01 mbar; (x) between 0.01 and 10 mbar; (xi) between 0.01 and 1 mbar; (xii) between 0.01 and 0.1 mbar; (xiii) between 0.1 and 10 mbar; (xiv) between 0.1 and 1 mbar; (xv) between 1 and 10 mbar; and (xvi) above 10 mbar.
- 10 49. A mass spectrometer as claimed in any preceding claim, wherein said ion mobility separator is maintained, in use, at a pressure such that a viscous drag is imposed upon ions passing through said ion mobility separator.
- 15 50. A mass spectrometer as claimed in any preceding claim, wherein in use said one or more transient DC voltages or said one or more transient DC voltage waveforms are initially provided at a first axial position and are then subsequently provided at second, then third different axial positions along said ion mobility separator.
- 20 51. A mass spectrometer as claimed in any preceding claim, wherein said one or more transient DC voltages or said one or more transient DC voltage waveforms move from one end of said ion mobility separator to another end of said ion mobility separator so that at least some ions are urged along said ion mobility separator.
- 25 52. A mass spectrometer as claimed in any preceding claim, wherein said one or more transient DC voltages or

- 14 -

said one or more transient DC voltage waveforms have at least 2, 3, 4, 5, 6, 7, 8, 9 or 10 different amplitudes.

53. A mass spectrometer as claimed in any preceding
claim, wherein the amplitude of said one or more
transient DC voltages or said one or more transient DC
voltage waveforms remains substantially constant with
time.

10 54. A mass spectrometer as claimed in any of claims 1-
52, wherein the amplitude of said one or more transient
DC voltages or said one or more transient DC voltage
waveforms varies with time.

15 55. A mass spectrometer as claimed in claim 54, wherein
the amplitude of said one or more transient DC voltages
or said one or more transient DC voltage waveforms
either: (i) increases with time; (ii) increases then
decreases with time; (iii) decreases with time; or (iv)
20 decreases then increases with time.

56. A mass spectrometer as claimed in claim 54, wherein
said ion mobility separator comprises an upstream
entrance region, a downstream exit region and an
intermediate region, wherein:

in said entrance region the amplitude of said one
or more transient DC voltages or said one or more
transient DC voltage waveforms has a first amplitude;

30 in said intermediate region the amplitude of said
one or more transient DC voltages or said one or more
transient DC voltage waveforms has a second amplitude;
and

- 15 -

in said exit region the amplitude of said one or more transient DC voltages or said one or more transient DC voltage waveforms has a third amplitude.

5 57. A mass spectrometer as claimed in claim 56, wherein the entrance and/or exit region comprise a proportion of the total axial length of said ion mobility separator selected from the group consisting of: (i) < 5%; (ii) 5-10%; (iii) 10-15%; (iv) 15-20%; (v) 20-25%; (vi) 25-30%;
10 (vii) 30-35%; (viii) 35-40%; and (ix) 40-45%.

58. A mass spectrometer as claimed in claim 56 or 57, wherein said first and/or third amplitudes are substantially zero and said second amplitude is
15 substantially non-zero.

59. A mass spectrometer as claimed in claim 56, 57 or 58, wherein said second amplitude is larger than said first amplitude and/or said second amplitude is larger
20 than said third amplitude.

60. A mass spectrometer as claimed in any preceding claim, wherein said one or more transient DC voltages or said one or more transient DC voltage waveforms pass in
25 use along said ion mobility separator with a first velocity.

61. A mass spectrometer as claimed in claim 60, wherein said first velocity: (i) remains substantially constant;
30 (ii) varies; (iii) increases; (iv) increases then decreases; (v) decreases; (vi) decreases then increases; (vii) reduces to substantially zero; (viii) reverses

- 16 -

direction; or (ix) reduces to substantially zero and then reverses direction.

62. A mass spectrometer as claimed in claim 60 or 61,
5 wherein said one or more transient DC voltages or said
one or more transient DC voltage waveforms causes some
ions within said ion mobility separator to pass along
said ion mobility separator with a second different
velocity.

10

63. A mass spectrometer as claimed in claim 60, 61 or
62, wherein said one or more transient DC voltages or
said one or more transient DC voltage waveforms causes
some ions within said ion mobility separator to pass
15 along said ion mobility separator with a third different
velocity.

64. A mass spectrometer as claimed in any of claims 60-
63, wherein said one or more transient DC voltages or
20 said one or more transient DC voltage waveforms causes
some ions within said ion mobility separator to pass
along said ion mobility separator with a fourth
different velocity.

25 65. A mass spectrometer as claimed in any of claims 60-
64, wherein said one or more transient DC voltages or
said one or more transient DC voltage waveforms causes
some ions within said ion mobility separator to pass
along said ion mobility separator with a fifth different
30 velocity.

66. A mass spectrometer as claimed in any of claims 60-
65, wherein the difference between said first velocity

- 17 -

and said second and/or third and/or fourth and/or fifth velocities is selected from the group consisting of: (i) less than or equal to 50 m/s; (ii) less than or equal to 40 m/s; (iii) less than or equal to 30 m/s; (iv) less than or equal to 20 m/s; (v) less than or equal to 10 m/s; (vi) less than or equal to 5 m/s; and (vii) less than or equal to 1 m/s;

67. A mass spectrometer as claimed in any of claims 60-
10 66, wherein said first velocity is selected from the
group consisting of: (i) 10-250 m/s; (ii) 250-500 m/s;
(iii) 500-750 m/s; (iv) 750-1000 m/s; (v) 1000-1250 m/s;
(vi) 1250-1500 m/s; (vii) 1500-1750 m/s; (viii) 1750-
2000 m/s; (ix) 2000-2250 m/s; (x) 2250-2500 m/s; (xi)
15 2500-2750 m/s; and (xii) 2750-3000 m/s.

68. A mass spectrometer as claimed in claim 60-67,
wherein said second and/or third and/or fourth and/or
fifth velocity is selected from the group consisting of:
20 (i) 10-250 m/s; (ii) 250-500 m/s; (iii) 500-750 m/s;
(iv) 750-1000 m/s; (v) 1000-1250 m/s; (vi) 1250-1500
m/s; (vii) 1500-1750 m/s; (viii) 1750-2000 m/s; (ix)
2000-2250 m/s; (x) 2250-2500 m/s; (xi) 2500-2750 m/s;
and (xii) 2750-3000 m/s.

25 69. A mass spectrometer as claimed in any preceding
claim, wherein said one or more transient DC voltages or
said one or more transient DC voltage waveforms has a
frequency, and wherein said frequency: (i) remains
substantially constant; (ii) varies; (iii) increases;
30 (iv) increases then decreases; (v) decreases; or (vi)
decreases then increases.

- 18 -

70. A mass spectrometer as claimed in any preceding claim, wherein said one or more transient DC voltages or said one or more transient DC voltage waveforms has a wavelength, and wherein said wavelength: (i) remains substantially constant; (ii) varies; (iii) increases; (iv) increases then decreases; (v) decreases; or (vi) decreases then increases.

10 71. A mass spectrometer as claimed in any preceding claim, wherein two or more transient DC voltages or two or more transient DC voltage waveforms pass simultaneously along said ion mobility separator.

15 72. A mass spectrometer as claimed in claim 71, wherein said two or more transient DC voltages or said two or more transient DC voltage waveforms are arranged to move: (i) in the same direction; (ii) in opposite directions; (iii) towards each other; (iv) away from each other.

20 73. A mass spectrometer as claimed in any preceding claim, wherein said one or more transient DC voltages or said one or more transient DC voltage waveforms passes along said ion mobility separator and at least one substantially stationary transient DC potential waveform is provided at a position along said ion mobility separator.

30 74. A mass spectrometer as claimed in any preceding claim, wherein said one or more transient DC voltages or said one or more transient DC voltage waveforms are repeatedly generated and passed in use along said ion mobility separator, and wherein the frequency of

- 19 -

generating said one or more transient DC voltages or
said one or more transient DC voltage waveforms: (i)
remains substantially constant; (ii) varies; (iii)
increases; (iv) increases then decreases; (v) decreases;
5 or (vi) decreases then increases.

75. A mass spectrometer as claimed in any preceding
claim, wherein in use a continuous beam of ions is
received at an entrance to said ion mobility separator.
10

76. A mass spectrometer as claimed in any of claims 1-
74, wherein in use packets of ions are received at an
entrance to said ion mobility separator.

15 77. A mass spectrometer as claimed in any preceding
claim, wherein in use pulses of ions emerge from an exit
of said ion mobility separator.

20 78. A mass spectrometer as claimed in claim 77, further
comprising an ion detector, said ion detector being
arranged to be substantially phase locked in use with
the pulses of ions emerging from the exit of the ion
mobility separator.

25 79. A mass spectrometer as claimed in claim 77 or 78,
further comprising a Time of Flight mass analyser
comprising an electrode for injecting ions into a drift
region, said electrode being arranged to be energised in
use in a substantially synchronised manner with the
30 pulses of ions emerging from the exit of the ion
mobility separator.

- 20 -

80. A mass spectrometer as claimed in any preceding claim, wherein said ion mobility separator is selected from the group consisting of: (i) an ion funnel comprising a plurality of electrodes having apertures therein through which ions are transmitted, wherein the diameter of said apertures becomes progressively smaller or larger; (ii) an ion tunnel comprising a plurality of electrodes having apertures therein through which ions are transmitted, wherein the diameter of said apertures remains substantially constant; and (iii) a stack of plate, ring or wire loop electrodes.

81. A mass spectrometer as claimed in any preceding claim, wherein said ion mobility separator comprises a plurality of electrodes, each electrode having an aperture through which ions are transmitted in use.

82. A mass spectrometer as claimed in any preceding claim, wherein each electrode has a substantially circular aperture.

83. A mass spectrometer as claimed in any preceding claim, wherein each electrode has a single aperture through which ions are transmitted in use.

84. A mass spectrometer as claimed in claim 81, 82 or 83, wherein the diameter of the apertures of at least 50%, 60%, 70%, 80%, 90% or 95% of the electrodes forming said ion mobility separator is selected from the group consisting of: (i) less than or equal to 10 mm; (ii) less than or equal to 9 mm; (iii) less than or equal to 8 mm; (iv) less than or equal to 7 mm; (v) less than or equal to 6 mm; (vi) less than or equal to 5 mm; (vii)

- 21 -

less than or equal to 4 mm; (viii) less than or equal to 3 mm; (ix) less than or equal to 2 mm; and (x) less than or equal to 1 mm.

5 85. A mass spectrometer as claimed in any preceding claim, wherein at least 50%, 60%, 70%, 80%, 90% or 95% of the electrodes forming the ion mobility separator have apertures which are substantially the same size or area.

10

86. A mass spectrometer as claimed in any of claims 1-79, wherein said ion mobility separator comprises a segmented rod set.

15 87. A mass spectrometer as claimed in any preceding claim, wherein said ion mobility separator consists of: (i) 10-20 electrodes; (ii) 20-30 electrodes; (iii) 30-40 electrodes; (iv) 40-50 electrodes; (v) 50-60 electrodes; (vi) 60-70 electrodes; (vii) 70-80 electrodes; (viii) 80-90 electrodes; (ix) 90-100 electrodes; (x) 100-110 electrodes; (xi) 110-120 electrodes; (xii) 120-130 electrodes; (xiii) 130-140 electrodes; (xiv) 140-150 electrodes; or (xv) more than 150 electrodes.

25 88. A mass spectrometer as claimed in any preceding claim, wherein the thickness of at least 50%, 60%, 70%, 80%, 90% or 95% of said electrodes is selected from the group consisting of: (i) less than or equal to 3 mm; (ii) less than or equal to 2.5 mm; (iii) less than or equal to 2.0 mm; (iv) less than or equal to 1.5 mm; (v) less than or equal to 1.0 mm; and (vi) less than or equal to 0.5 mm.

- 22 -

89. A mass spectrometer as claimed in any preceding claim, wherein said ion mobility separator has a length selected from the group consisting of: (i) less than 5 cm; (ii) 5-10 cm; (iii) 10-15 cm; (iv) 15-20 cm; (v) 20-
5 25 cm; (vi) 25-30 cm; and (vii) greater than 30 cm.

90. A mass spectrometer as claimed in any preceding claim, wherein at least 10%, 20%, 30%, 40%, 50%, 60%,
10 70%, 80%, 90%, or 95% of said electrodes are connected to both a DC and an AC or RF voltage supply.

91. A mass spectrometer as claimed in any preceding claim, wherein axially adjacent electrodes are supplied with AC or RF voltages having a phase difference of
15 180°.

92. A mass spectrometer as claimed in any preceding claim, further comprising an ion source selected from the group consisting of: (i) Electrospray ("ESI") ion source; (ii) Atmospheric Pressure Chemical Ionisation ("APCI") ion source; (iii) Atmospheric Pressure Photo Ionisation ("APPI") ion source; (iv) Matrix Assisted Laser Desorption Ionisation ("MALDI") ion source; (v) Laser Desorption Ionisation ("LDI") ion source; (vi) Inductively Coupled Plasma ("ICP") ion source; (vii) Electron Impact ("EI") ion source; (viii) Chemical Ionisation ("CI") ion source; (ix) a Fast Atom Bombardment ("FAB") ion source; and (x) a Liquid Secondary Ions Mass Spectrometry ("LSIMS") ion source.
25
30

93. A mass spectrometer as claimed in any of claims 1-91, further comprising a continuous ion source.

- 23 -

94. A mass spectrometer as claimed in any of claims 1-91; further comprising a pulsed ion source.
95. An ion mobility separator for separating ions according to their ion mobility, said ion mobility separator comprising a plurality of electrodes wherein in use one or more transient DC voltages or one or more transient DC voltage waveforms are progressively applied to said electrodes so that at least some ions having a first ion mobility are separated from other ions having a second different ion mobility.
96. An ion mobility separator for separating ions according to their ion mobility, said ion mobility separator comprising a plurality of electrodes wherein in use one or more transient DC voltages or one or more transient DC voltage waveforms are progressively applied to said electrodes so that ions are moved towards a region of the ion mobility separator wherein at least one electrode has a potential such that at least some ions having a first ion mobility will pass across said potential whereas other ions having a second different ion mobility will not pass across said potential.
97. An ion mobility separator for separating ions according to their ion mobility, said ion mobility separator comprising a plurality of electrodes wherein in use one or more transient DC voltages or one or more transient DC voltage waveforms are progressively applied to said electrodes so that:
- (i) ions are moved towards a region of the ion mobility separator wherein at least one electrode has a first potential such that at least some ions having

- 24 -

first and second ion mobilities will pass across said first potential whereas other ions having a third different ion mobility will not pass across said first potential; and then

- 5 (ii) ions having said first and second ion mobilities are moved towards a region of the ion mobility separator wherein at least one electrode has a second potential such that at least some ions having said first ion mobility will pass across said second potential whereas other ions having said second ion mobility will not pass across said second potential.

- 10 98. A method of mass spectrometry comprising:
 receiving ions in an ion mobility separator
15 comprising a plurality of electrodes;
 progressively applying to said electrodes one or more transient DC voltages or one or more transient DC voltage waveforms so that at least some ions having a first ion mobility are separated from other ions having
20 a second different ion mobility.

- 25 99. A method of mass spectrometry comprising:
 receiving ions in an ion mobility separator
 comprising a plurality of electrodes;
 progressively applying to said electrodes one or more transient DC voltages or one or more transient DC voltage waveforms so that ions are moved towards a region of the ion mobility separator wherein at least one electrode has a potential such that at least some
30 ions having a first ion mobility will pass across said potential whereas other ions having a second different ion mobility will not pass across said potential.

- 25 -

100. A method of mass spectrometry comprising:

receiving ions in an ion mobility separator comprising a plurality of electrodes;

progressively applying to said electrodes one or
5 more transient DC voltages or one or more transient DC voltage waveforms so that ions are moved towards a region of the ion mobility separator wherein at least one electrode has a first potential such that at least some ions having a first and second ion mobilities will
10 pass across said first potential whereas other ions having a third different ion mobility will not pass across said first potential; and then

progressively applying to said electrodes one or
15 more transient DC voltages or one or more transient DC voltage waveforms so that ions having said first and second ion mobilities are moved towards a region of the ion mobility separator wherein at least one electrode has a second potential such that at least some ions having said first ion mobility will pass across said
20 second potential whereas other ions having said second ion mobility will not pass across said second potential.

101. A method of ion mobility separation comprising:

receiving ions in an ion mobility separator
25 comprising a plurality of electrodes;

progressively applying to said electrodes one or more transient DC voltages or one or more transient DC voltage waveforms so that at least some ions having a first ion mobility are separated from other ions having
30 a second different ion mobility.

102. A method of ion mobility separation comprising:

- 26 -

receiving ions in an ion mobility separator comprising a plurality of electrodes;

5 progressively applying to said electrodes one or more transient DC voltages or one or more transient DC voltage waveforms so that ions are moved towards a region of the ion mobility separator wherein at least one electrode has a potential such that at least some ions having a first ion mobility will pass across said potential whereas other ions having a second different ion mobility will not pass across said potential.

103. A method of ion mobility separation comprising:
receiving ions in an ion mobility separator comprising a plurality of electrodes;

15 progressively applying to said electrodes one or more transient DC voltages or one or more transient DC voltage waveforms so that ions are moved towards a region of the ion mobility separator wherein at least one electrode has a first potential such that at least some ions having a first and second ion mobilities will pass across said first potential whereas other ions having a third different ion mobility will not pass across said first potential; and then

25 progressively applying to said electrodes one or more transient DC voltages or one or more transient DC voltage waveforms so that ions having said first and second ion mobilities are moved towards a region of the ion mobility separator wherein at least one electrode has a second potential such that at least some ions having said first ion mobility will pass across said second potential whereas other ions having said second ion mobility will not pass across said second potential.

SMEG

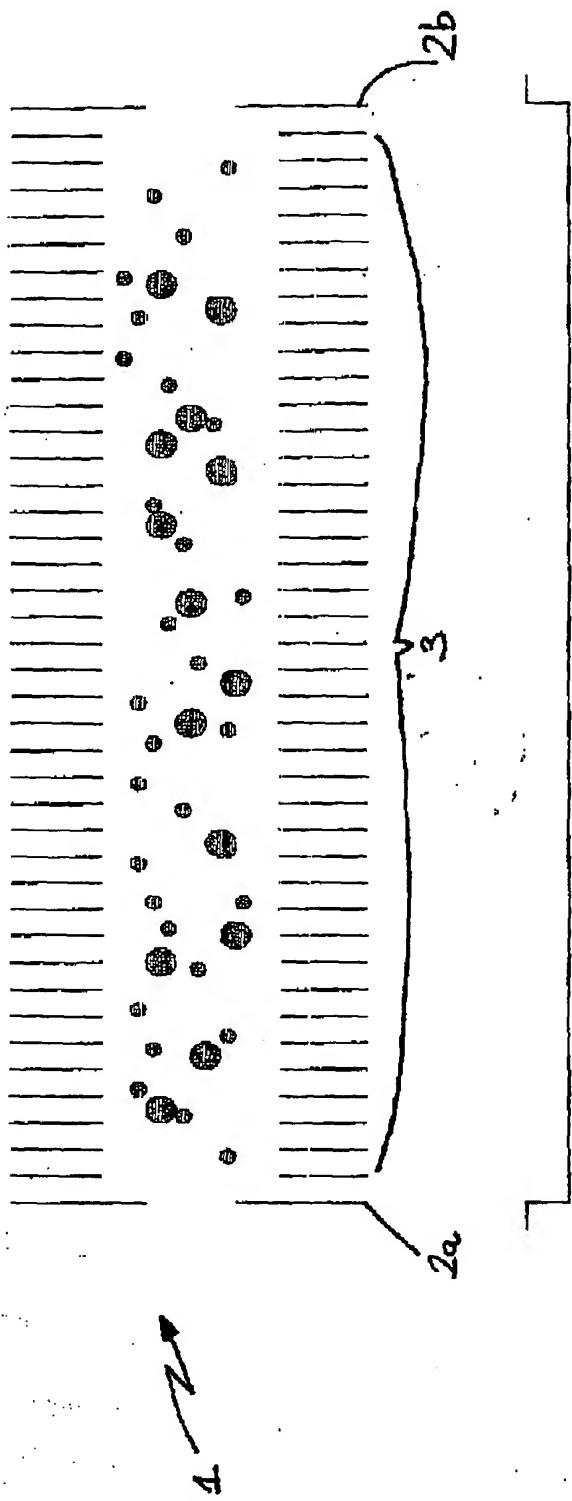


Fig. 1

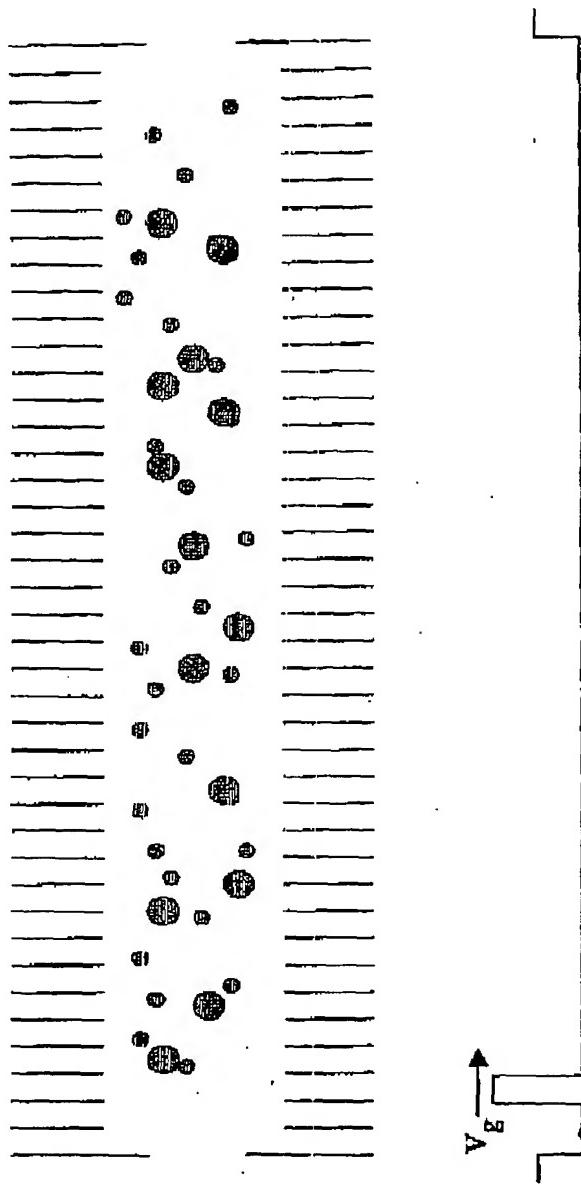


Fig.2



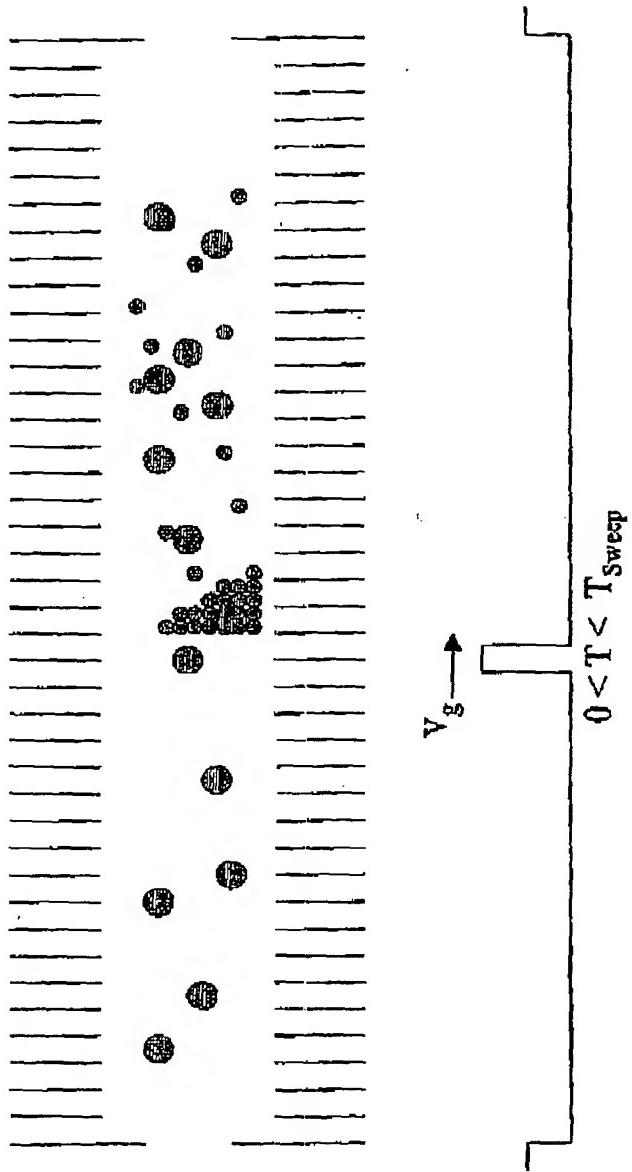


Fig. 3

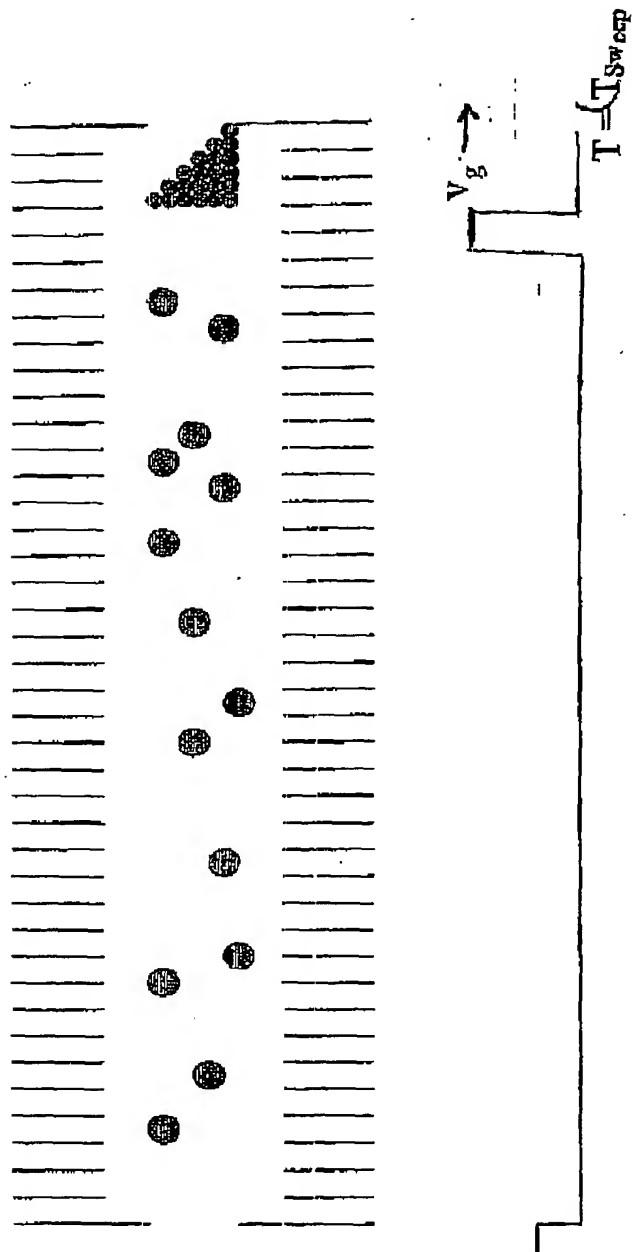


Fig. 4



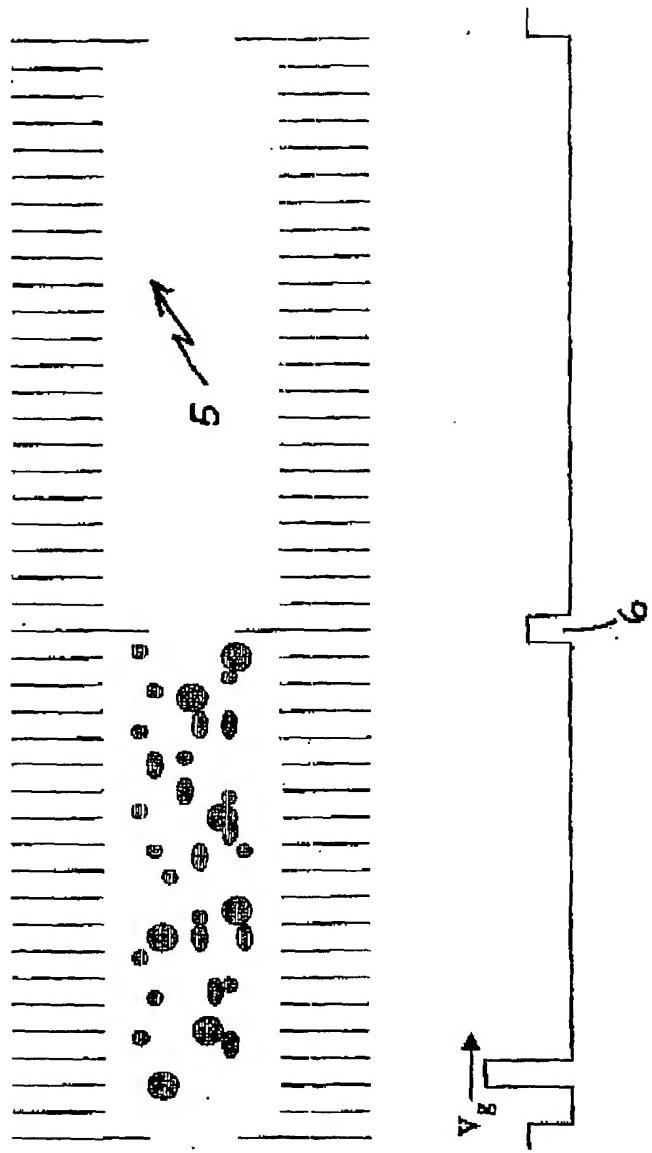


Fig. 5

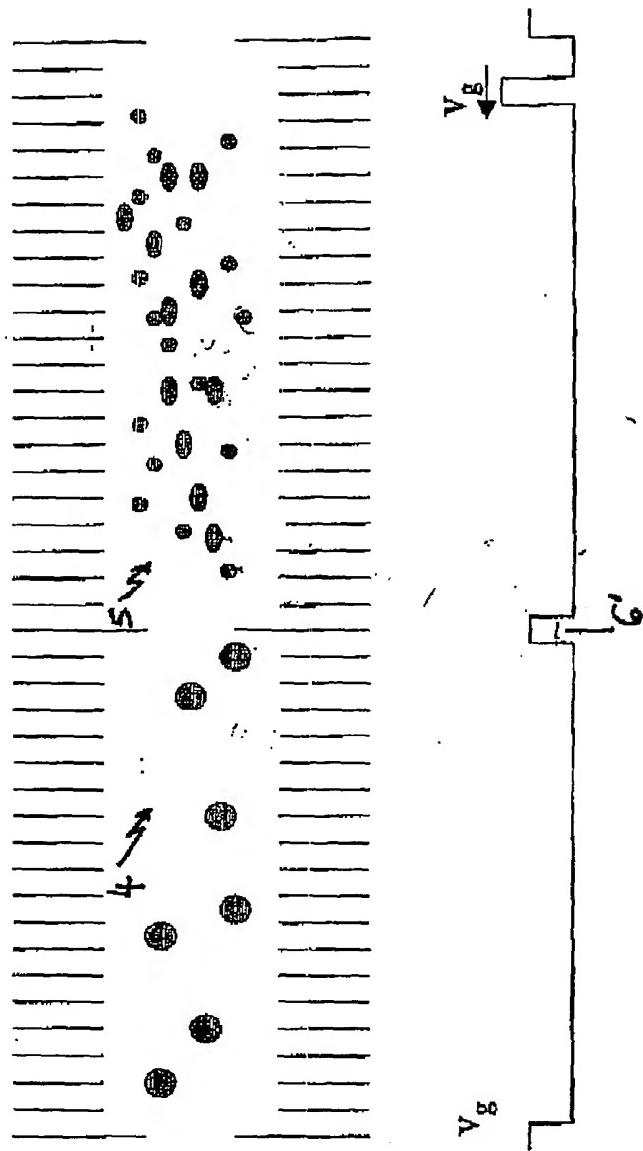


Fig. 6

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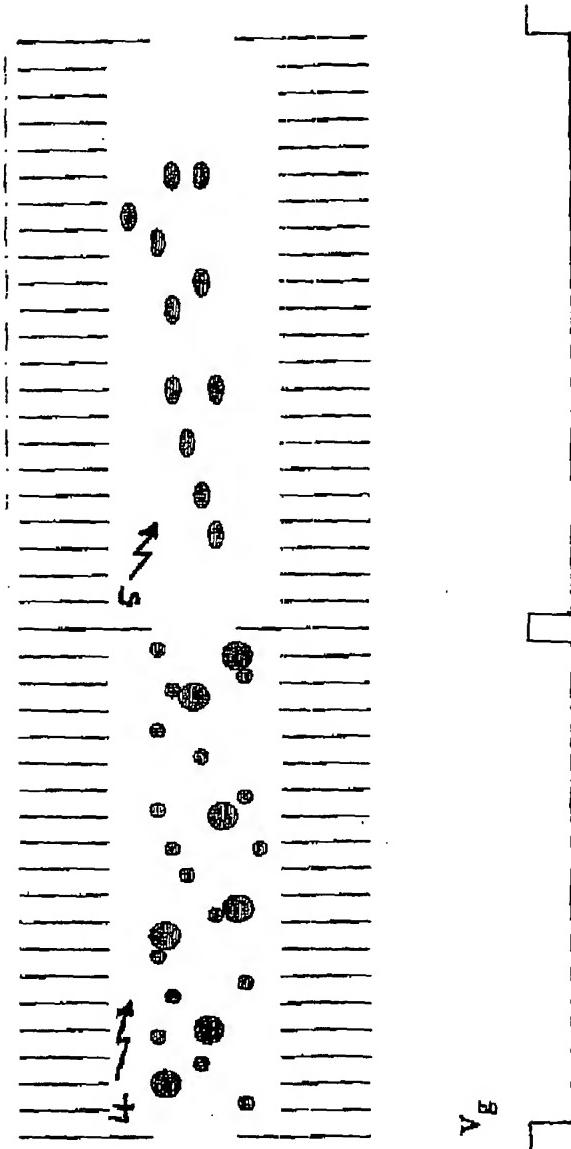


Fig. 7

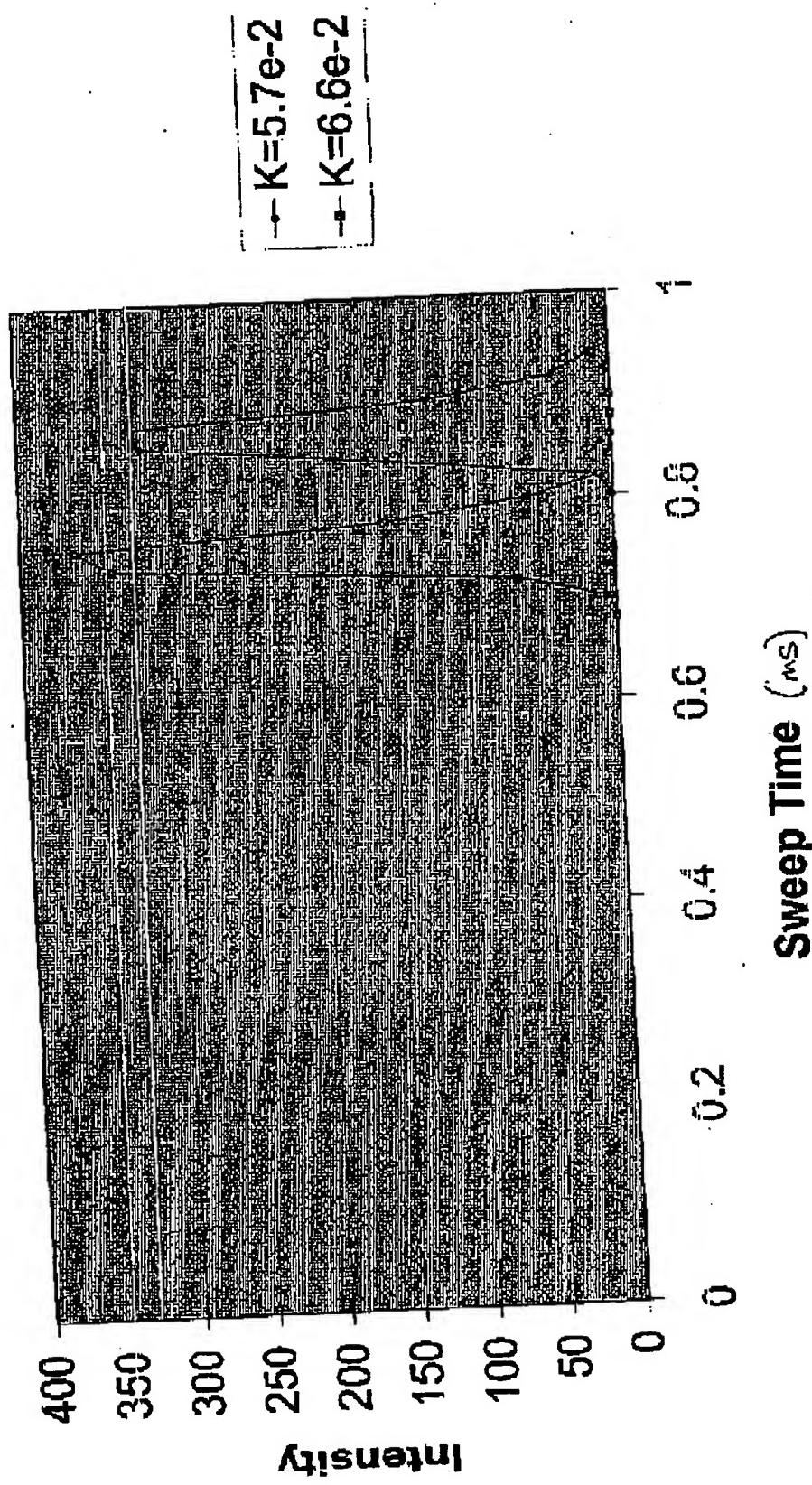
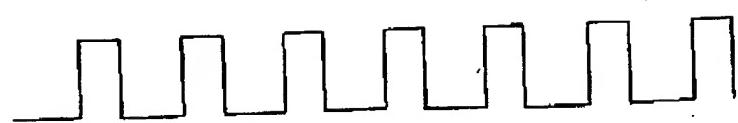
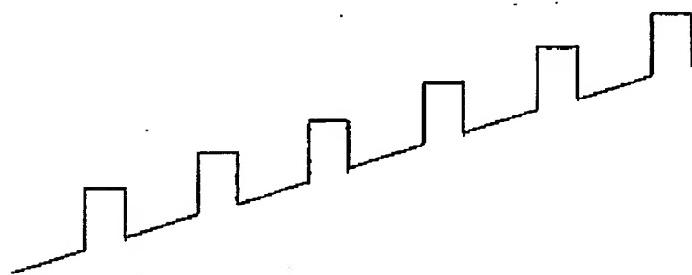


Figure 8

A



B



C

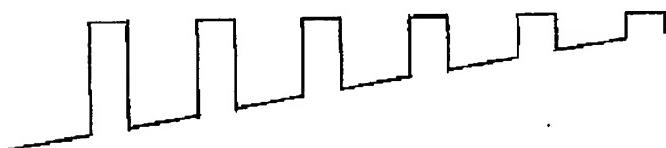


Fig. 9

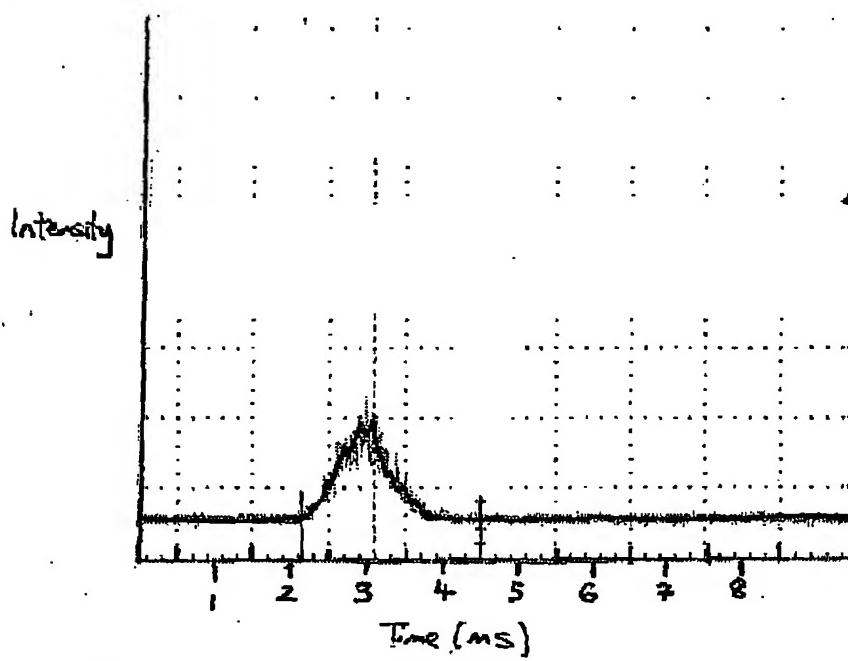
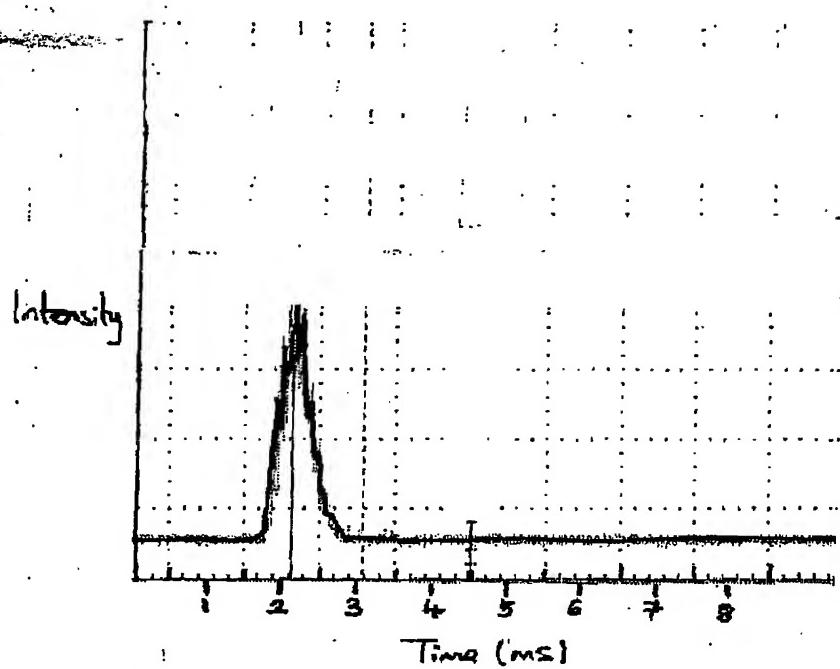


Fig. 10

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